

Contamination Control Requirements Manual

NS/Safety and Test Operations Division

February 2005

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**National Aeronautics and
Space Administration**

**Lyndon B. Johnson Space Center
Houston, Texas**

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Contamination Control Requirements Manual

February 16, 2005

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Revisions and Changes

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A	1	Change 1	August 1980
B		Revision B	November 1982
C		Revision C	February 1994
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1.0 INTRODUCTION

1.1 Purpose

This JSC Contamination Control Requirements Manual establishes the minimum requirements and controls necessary to establish and maintain an effective contamination control system.

1.2 Applicability

This manual is applicable to JSC organizations and on-site and off-site contractors who are responsible for designing, developing, manufacturing, inspecting, processing for shipment, and testing of ground, flight and flight-related equipment.

1.3 Acronyms

Acronyms for terminology used in this manual are contained in Appendix A.

1.4 Trade Names

The use of trade names of commercially available products does not constitute an endorsement by NASA nor does it imply that there are no other suitable products available.

1.5 Waivers and Deviations

If compliance with the requirements of this manual is not possible, the responsible technical organization shall initiate a waiver or deviation and submit it in sufficient time to allow for proper evaluation and disposition through the formal concurrence and approval process. All requests for waivers and deviations shall be submitted by memorandum to the Director, Safety and Mission Assurance (S&MA), the approval authority. The S&MA Director can delegate the approval authority to the Safety and Test Operations Division by memorandum for individual or all waiver requests.

1.6 Revisions and Changes

All revisions and changes to this manual shall be approved by formal JSC concurrence procedures, as specified in applicable JSC management documentation.

2.0 PROCUREMENT

Appropriate contamination control requirements shall be included in procurement documents for flight and flight-related equipment, environmental test facilities, facility fluid systems, precision-cleaned packaging materials, and garment maintenance services by the requirement initiator. The Safety and Test Operations Division will, upon request, assist JSC organizations in the selection of cost-effective contamination control requirements.

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2.1 Contamination Control Plan

The purpose of a contamination control plan is to ensure product cleanliness. The requirement for a contamination control plan shall be included in procurements for spacecraft and spacecraft systems and subsystems. Procurements for items of lesser complexity may also require a contamination control plan when stringent cleanliness requirements are specified or when contamination control is important. The Safety and Test Operations Division shall review and approve the contamination control plan.

2.2 Cleanliness Certification

The requirement initiator shall assure that procurement documents for systems, subsystems, and major assemblies require that the contractor submit a certification of cleanliness, which identifies the cleanliness level to which the contract item was cleaned and verified. The cleanliness level certified by the contractor shall be correlated to the levels identified in Table IV, Appendix B of this document. The verification methods and data shall be provided by the contractor.

2.3 Review Of Procurement Documentation

Contamination control provisions of contracts shall be submitted to the S&MA and Engineering Directorates, or approved alternate, for review and approval prior to procurement.

3.0 ACCOMPANYING DOCUMENTATION

The documentation accompanying precision, VC + UV, or VC level cleaned items shall be reviewed for compliance with applicable contract requirements, including any certification of cleanliness. Such documentation and/or item certification shall be maintained as a permanent record traceable to the item received. This includes items fabricated or assembled on site from externally supplied parts, such as flex hose assemblies.

4.0 SURFACE CLEANLINESS LEVELS

The responsible design or user organization shall select cleanliness levels from the following two categories that meet a wide range of cleanliness needs.

- a. Visible cleanliness. Visible cleanliness levels are described as “qualitative” in that verification and/or inspection of these levels is visual. However, these levels are not considered inadequate, since the application of these levels must be viewed with respect to hardware design and operation. These levels represent a cost-effective alternative to precision cleanliness levels and offer greater flexibility for the appropriate design or using organizations. Visible cleanliness levels may be used as either interim or final cleanliness levels.
- b. Precision cleanliness. Precision cleanliness levels specify the maximum quantity of particulate and/or nonvolatile residue (NVR) permitted on external or internal surfaces of the hardware after cleaning.

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4.1 Visible Cleanliness Level Requirements

Three visible cleanliness levels are defined for JSC hardware. The levels include: Generally Clean (GC), Visibly Clean (VC), and Visibly Clean + Ultraviolet (VC+UV).

4.1.1 GC Level

GC level clean materials shall be free of manufacturing residue, dirt, oil, grease, processing debris, or other extraneous contamination.

Note: Cleaning is required only if the item does not pass inspection. Heat-sealed bagging protection is not required, but normal protection is required for handling, shipping, and storage. The GC level should be specified for hardware that is not sensitive to contamination and is easily and quickly cleaned or re-cleaned.

4.1.2 VC Level

VC cleaned hardware shall be cleaned and verified to be free of all particulate and non-particulate material visible to the normal unaided eye. Hardware cleaned to VC levels shall be continuously protected using heat-sealed bagging. Where requirements exist for cleaning only internal surfaces where there is fluid contact, especially for larger components and tubing, only sealing of the fluid ports shall be required.

Note: Borescopes, mirrors, or other inspection devices may be used to increase accessibility during inspection, but magnifying lenses may be used only to further identify visible contaminants. Where configuration, color, or other item characteristics interfere with visual observation, the wipe test and the water break test shall be used to augment visual inspections.

4.1.3 VC + UV Level

The VC + UV cleanliness level provides a surface condition free of all visible particulate and non-particulate contamination augmented by inspection under UV light (Ultraviolet light of 3,200 to 3,800 angstroms wavelength). Any evidence of fluorescence during UV inspection shall be cause for re-cleaning. If the surface to be inspected is inaccessible, a wipe test shall be performed and the wiping medium shall be inspected under UV light. All items cleaned to VC+UV level shall be continuously protected using heat-sealed double bagging, unless it is not practical.

4.2 Precision Cleanliness Level Requirements

The responsible design or user organization shall select the precision cleanliness level from Table IV, Appendix B. Personnel trained in accordance with Section 15.0 of this manual shall perform sampling and verification tasks to attain the specified precision cleanliness levels. Evidence of inspection and acceptance shall be documented by the cleanroom management.

5.0 Environmentally Controlled Areas (ECAs)

Areas designated as ECAs include cleanrooms, laminar flow clean workstations, and controlled work areas (CWAs). All cleanrooms used for final cleanliness verification, assembly, testing, and packaging of precision, VC + UV, and VC level cleaned articles, and all laminar flow clean work stations used to process flight or flight-related equipment shall be certified by a documented procedure to meet the requirements in Table I, Appendix B.

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5.1 Types And Classification Of ECAs

5.1.1 Laminar Flow Clean Work Stations

Laminar flow clean workstations shall be certified and maintained to the ISO Class 5 level determined by its application within the user organization. In addition, the laminar flow clean workstations shall meet the requirements specified in Sections 5.2 and 5.4.

5.1.2 Controlled Work Area (CWA) Classification

Laboratories, special workrooms, vacuum chambers, or other facilities that require environmental and contamination controls, which are not cleanrooms but do meet the minimum requirements of Sections 5.2 and 5.5, shall be identified as controlled work areas (CWAs).

5.1.3 Cleanrooms

Cleanliness classes of cleanrooms used at JSC and offsite contractors providing cleanliness certified items shall comply with the airborne particle cleanliness requirements in Table 1, Appendix B. The Safety and Test Operations Division shall concur in the selection of cleanroom classes for flight and flight-related equipment.

Note: FED-STD-209E was cancelled on November 29, 2001. It has been superseded by ISO 14644 Parts 1 and 2. ISO 14644 describes several types of cleanrooms, which include conventional and laminar airflow designs. Table 1 in Appendix B provides a comparison of cleanroom classes defined in ISO 14644 Part 1 and FED-STD-209E. with ISO 14644 Parts 1 and 2. The Safety and Test Operations Division will, upon request, assist JSC organizations and offsite contractors with the selection of an appropriate cleanroom design.

5.2 ECA Operating Requirements

Table II, Appendix B, provides a ready reference matrix of requirements relating to ECAs. The operations shall be controlled by approved protocols and procedures to meet these requirements for the ECA in each facility. Minimum garment requirements for ECAs are listed in Table III, Appendix B. The Safety and Test Operations Division shall approve cleanroom garment requirements for ECAs.

5.2.1 Personnel Training

ECA personnel involved in contamination control activities shall be trained to meet the requirements in Section 16.0.

5.3 Cleanroom Requirements

Cleanroom operating requirements shall be established to ensure effective contamination control of the item to be processed. The items described below are mandatory for JSC cleanrooms.

- Airborne Particle Monitoring Airborne particle monitoring shall be performed to ensure continued compliance with Table 1, Appendix B.
- Positive Pressure. The minimum positive pressure differential between the cleanroom and any adjacent area subject to lesser cleanliness requirements shall be 1.27 millimeters (0.05 inches) of water, with all entryways closed.

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Note: When the entryways are open, there should be adequate blower capacity to maintain an outward flow of air from the cleanroom to minimize contaminants migrating into the room.

- Temperature Range. The temperature in the cleanrooms shall be maintained in the range 19-24 C (67-75 F) with the exception of those laboratories or work areas for which other temperatures are actually required by the items being processed.
- Relative Humidity (RH). The RH in cleanrooms shall be maintained between 30% and 70 % unless other ranges are actually required for the items being processed.

Note: Corrosion of parts can occur at RH above 50%. At low RH, surface static charge on dielectric materials or parts can result in particle deposition on the surface due to electrostatic attractive forces.

- Cleanroom Lighting. At all work locations within the cleanroom, shadowless uniform incident lighting of 800 to 1,000 lumens (75 to 100 ft-candles, 24 to 30 meter-candles) per square meter shall be provided.

Note: Certain hardware may require higher luminosity.

Note: Cleanroom requirements may be selected from, but are not limited to, those contained in ISO 14644 Parts 1, 3, and 5.

5.3.1 Cleanroom Operating Procedures

Documented operating procedures are required for all classes of cleanrooms. The procedures shall describe the cleanroom monitoring, personnel discipline, packaging, and garmenting functions to comply with the Tables II, III, V and VI.

5.4 Laminar Flow Clean Work Station Requirements

In addition to ECA requirements specified in Section 5.2, airflow velocity shall be maintained at 27.5 meters per minute (90 ft per minute) average with a uniformity of $\pm 20\%$ across the entire area of the exit. The laminar flow clean work station shall be monitored at regular intervals to verify continued compliance with the requirements in Table II, Appendix B. Monitoring and maintenance records shall be maintained for each laminar flow clean work station. The requirements for certification of laminar flow clean workstations are specified in Section 6.0.

5.4.1 Operating Procedures

Documented and approved procedures are required for all operations laminar flow clean workstations. The procedures shall describe the monitoring, personnel discipline, packaging, and garmenting functions for each facility.

5.5 Controlled Work Area Requirements

The requirements stated below are in addition to ECA requirements specified in Section 5.2 and shall be used where a high degree of shop cleanliness is required. Housekeeping procedures, personnel controls, and contaminant-generation constraints shall be specified in operating procedures for CWAs to obtain and maintain an acceptable level of work area cleanliness and to protect work piece cleanliness. Although annual certification is not required for CWAs, the minimum requirements stated below shall be observed.

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5.5.1 Facility Requirements

- The environment in and around the cleanroom shall be filtered. Note: An anteroom is not required for gloveboxes or flow benches.
- Temperature may be controlled for personnel comfort; however, humidity shall be controlled to the extent necessary to prevent condensation or corrosion on all surfaces, or to preclude buildup of electrical static charges.
- A separate area shall be provided at the entrance to a cleanroom for storage of cleanroom garments and for dressing. This area shall be separated from the operating areas by an enclosed anteroom or by a partition.
- CWAs shall be protected from contamination resulting from overhead operations such as cranes, high-lifts, or facility maintenance.

Note: A flame-retardant plastic covering may be used for this purpose.

5.5.2 CWA Operations

- Visual or wipe evidence of dust, dirt, or oils shall be reason for ceasing operations in the immediate area and cleaning the affected area to a VC level. Articles subjected to out-of-control conditions shall be inspected to verify cleanliness at VC level.
- All parts, equipment, tools, test fixtures, and apparatus shall be cleaned and verified to VC level before they are placed in the CWA.
- Assembly, disassembly, modification, or repair of systems or subsystems, which require that a system cleanliness level be maintained, shall be performed under localized clean conditions.
- All exposed surfaces, lines, or parts shall be protected with standard closures or be covered with certified clean inner packaging film as specified in Table V, Appendix B.
- Contaminant-generating operations, such as sanding, grinding, chipping, drilling, welding, and painting, shall not be performed in CWAs unless specifically approved by the responsible quality organization. Appropriate controls and monitoring shall be exercised during such operations.

6.0 CERTIFICATION OF CLEANROOMS AND LAMINAR FLOW CLEAN WORK STATIONS

Newly installed cleanrooms and laminar flow clean workstations shall be initially certified before operation. All cleanrooms and laminar flow clean workstations shall be recertified annually.

6.1 Instrument Calibration

All instruments and applicable equipment, including permanent cleanroom monitoring equipment, used during the certification process shall have current calibration status.

6.2 Documentation

A documented procedure NX-PRE-003 or equivalent, shall be used for certification of cleanrooms and laminar flow work stations.

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Note: The Safety and Test Operations Division will, upon request, help prepare the certification procedure. Procedures for certification verification are provided in NX-PRE-003, NT-QAS-018, ISO 14644 Parts 2 and 3, IEST-RP-CC002 and IEST-RP-CC006.

6.3 Testing Requirements

The certification procedure shall, as a minimum, consist of the tests described below. Consistent performance shall be demonstrated by performing and recording the airborne particle sampling, temperature checks, and RH checks for 3 consecutive days, unless the cleanrooms are monitored daily. Re-certification requirements are given in Section 5.6.

Note: ISO 14644 Part 3 provides guidelines for performing the tests.

6.3.1 Cleanroom Testing Requirements

The following tests are required for cleanrooms.

- HEPA filter particulate leak test to verify the absence of leaks. Sampling shall be performed at a scan rate of approximately 2 meters (approximately 6 feet) per minute at a distance of 8 to 15 centimeters (3 to 6 inches) from the filter protection screen.
- Room airborne particulate counting. The particle count shall be determined for particle size of 0.5 μm and larger and 5.0 μm and larger (Table I, Appendix B).
- Temperature and relative humidity (RH) within the cleanroom.
- Differential air pressure to verify that the facility maintains the specified pressure difference between the cleanroom and the surrounding area, and between the separate spaces within the installation.
- Light intensity to verify that the specified lighting levels and the uniformity of lighting within the room have been met.

6.3.2 Laminar Flow Clean Work Station Testing Requirements

The testing requirements specified in Section 6.3.1 also shall be used for certification of laminar flow clean workstations with two exceptions.

- For the HEPA filter leak test, the probe shall be scanned at a distance of 5 to 10 centimeters (2 to 4 inches) from the filter by overlapping horizontal passes.
- Airflow velocity shall be maintained at 27.5 meters per minute (90 feet per minute) average with a uniformity of $\pm 20\%$ across the entire area of the exit.

6.4 Flammable and Toxic Fluid Facilities

At JSC, the Safety and Test Operations Division and the Space Medicine and Health Care Systems Office shall evaluate and approve cleanrooms and laminar flow clean workstations, which contain cleaning facilities using flammable and/or toxic fluids before certification.

6.5 Re-Certification

All JSC cleanrooms and laminar flow clean workstations shall be re-certified annually. Evaluation for re-certification shall include all items required for initial certification. More frequent re-certification shall be performed for special applications or when requested by the user organization.

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6.6 Certifying Organization

Certification or re-certification of cleanrooms and laminar flow clean workstations shall be performed by a qualified independent organization, as approved by memorandum by the Safety and Test Operations Division.

Note: The certifying organization may be an external vendor. If an external vendor cannot be engaged in a timely manner, the Safety and Test Operations Division may perform the certification of the facility.

6.7 Certification Decal

A certification decal shall be affixed to all cleanrooms and workstations that specifies the environment classification and the date of certification or re-certification. For JSC facilities, decals shall include S&MA Directorate personnel approvals.

7.0 ESD CONTROL PROGRAM

The presence of electrically charged surfaces has two detrimental effects. ESD sensitive Electrical or electronic equipment can be damaged and charged surfaces tend to attract contaminant particles. An effective ESD control program shall be developed for ESD sensitive items that meet the requirements given in Table VI, Appendix B.

8.0 CLEANING PROCESS CONTROL REQUIREMENTS

8.1 Visible Cleanliness Requirements

The user organization shall implement the process controls described in this section to achieve the specified visible cleanliness requirements.

8.1.2 Visible Cleanliness Levels

The visible cleanliness levels, GC, VC, and VC + UV, have been defined in Section 4.1.

8.1.3 Cleaning Methods and Materials

Cleaning with an approved, compatible solvent is mandatory for VC and VC + UV level cleaned items, unless other methods are required by the hardware in question. All fluids, equipment, and facilities used for cleaning to the VC or VC + UV cleanliness levels shall be subject to the same minimum requirements specified for pre-cleaning procedures (Section 8.2.1). GC level cleaned items do not require cleaning before inspection. Cleaning is required only if the item does not pass GC inspection.

8.1.4 Handling

All items cleaned to the GC, VC, and VC + UV levels shall be handled as given below.

- GC level. Gloves are not required for the handling of GC items.
- VC level. Items cleaned to the VC level shall be handled with gloves if so specified by the responsible design or user organization.
- VC + UV level. Items cleaned to the VC + UV level shall be handled with approved gloves and forceps or tweezers.

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8.1.5 Inspection

Inspection of visually cleaned items shall be performed in accordance with Section 4.1.

8.1.6 Packaging Requirements

Specific packaging requirements exist for items cleaned to visible cleanliness levels as described in Section 4.1. General packaging requirements are detailed in Sections 9 and 10. The requirements stated below supplement these packaging requirements. Procurement documents shall reflect specific packaging requirements selected from Section 9.1 when visible cleanliness levels are specified.

8.1.6.1 GC Level

The GC cleanliness level has no specific contamination control packaging requirements. Protective packaging shall be provided during handling, shipping, and storage for GC hardware for subsequent space flight and for GC hardware in transit between facilities. Packaging shall be performed in an area where the cleanliness integrity of the article being processed is not jeopardized, preferably in a CWA.

Note: Acceptable means of protection include plastic boxes with snug-fitting covers or reusable plastic, non-heat-sealable bags. Hardware-compatible foam or other acceptable means of cushioning may be employed, if necessary.

8.1.6.2 VC Level

The VC cleanliness level requires packaging only in a single bag as specified in Table V, Appendix B. The packaging material shall be cleaned and visually verified to the VC level as a minimum. All packaging operations shall be performed within a CWA.

8.1.6.3 VC + UV Level

The VC + UV cleanliness level requires the use of double bags as specified in Section 4.1 and Table V, Appendix B, unless it is not practical. The *inner* packaging materials shall be cleaned and visually verified to the VC + UV level, as a minimum. All packaging operations shall be performed within an ISO Class 8 ECA or better (Table 1, Appendix B).

8.1.7 Identification, Certification, And Storage

8.1.7.1 GC Level

This level does not require a cleanliness certification decal, since protective packaging for contamination control is not required. Nominal storage requirements shall be established, as necessary, considering parameters such as length of storage and growth of biological organisms (mold or fungus, for example).

8.1.7.2 VC and VC + UV Levels

Items processed to the VC or VC + UV cleanliness levels shall be marked with a decal containing item identification, inspection, and certification of cleanliness information according to Section 8.7. Storage, environmental control, inspection, access controls, and post-storage decontamination requirements are specified in Section 11.

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8.2 Precision Cleaning Requirements

8.2.1 Gross Cleaning

Each item requiring precision cleaning shall be gross cleaned to the VC level before placing it in a cleanroom or clean workstation. The gross cleaning process shall be controlled by approved detailed procedures.

8.2.1.1 Cleaning Fluids

The cleaning fluids selected for use as gross cleaning solutions shall be controlled during use to maintain cleaning effectiveness and compatibility with the type of material being cleaned.

8.2.1.3 Inspection

Before precision cleaning, all gross cleaned items shall be inspected to the VC level according to Section 4.1.

8.2.1.4 Packaging and Storage

Gross cleaned items shall be packaged for interim storage or for subsequent precision cleaning according to the requirements for VC level described in Sections 4.1 and 7.1.6.2.

8.2.2 Precision Cleanliness Levels

Precision cleanliness levels have been defined in Table IV, Appendix B. The user organization shall specify the precision cleanliness levels selected from Table IV, Appendix B.

8.2.3 Precision Cleaning Process Controls

For all fluids, equipment, and facilities used for precision cleaning, the following minimum requirements shall be observed for contamination control.

8.2.3.1 Cleaning Fluid Requirements

Cleaning fluids selected for visible or precision cleaning shall be nontoxic, non-explosive, non-corrosive and non-flammable. They shall be compatible with the material being cleaned and should be environmentally friendly (recyclable, recoverable or disposable with low ozone depleting potential). The cleaning fluids used shall be procured and controlled by documented requirements in accordance with SE-S-0073. The final rinse and verification fluids shall be analyzed before use to determine compliance with the specified requirements.

8.2.3.2 Cleaning Operations

Precision cleaning shall be performed in a cleanroom using approved cleaning agents. All precision cleaning processes shall be controlled by approved documented procedures.

8.2.4 Cleanliness Verification

Cleanliness verification shall be performed in accordance with approved procedures.

8.2.5 Packaging Requirements

All precision cleaned items shall be packaged in accordance with Section 10 of this document immediately after cleaning and drying.

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9.0 REQUIREMENTS FOR PRECISION CLEANED PACKAGING MATERIAL

The material cleanliness and packaging requirements for the procurement of packaging materials used for the packaging of precision cleaned components are specified in this section. Materials shall be of the type specified in Table V, Appendix B. These requirements also apply to packaging materials for VC and VC + UV cleanliness level items.

9.1 Packaging Requirements

All packaging documentation shall reflect the requirements stated below.

9.1.2 Cleanliness Level

Outer packaging material shall be cleaned to VC level. *Inner* packaging material shall be precision cleaned to the appropriate precision cleanliness level in accordance with the hardware requirements.

All bags, sheeting, tubing, roll stock, and other cleaned packaging material shall be double bagged as specified in Section 9 and Table V, Appendix B. The inner bag shall be constructed of the same material as the one being packaged (for example, nylon film packaged in nylon bags). Roll stock shall be wound on clean cores made from non-dusting plastic or metal.

Note: Any requirement for inner packaging materials precision cleaned to levels stricter than Level 100 (such as Level 50 or Level 25) requires the concurrence of the Safety and Test Operations Division.

9.1.3 Environmental Controls

All processing and inspection operations shall be conducted within an environment compatible with the required cleanliness level for the packaging material being processed. Electrostatic charging will attract particles and shall be minimized during handling of plastic film.

9.1.4 Visual Inspection Requirements

Visual inspection shall be performed with the unaided eye. No evidence of oil, grease, water, solvents, paints, ink, dirt, metal chips, labels, preservatives, or other foreign matter shall be permitted on the external surfaces or the internal surfaces of intimate packaging materials. This requirement also applies to the internal surfaces of the overwrap packaging.

9.1.5 Cleanliness Verification

A rinse test shall be performed according to an approved standard procedure to verify compliance with the required cleanliness level.

9.1.6 Certification

The supplier shall furnish certification with each package, showing evidence of compliance with these requirements as specified in the procurement documents.

10.0 PACKAGING OF PRECISION CLEANED PARTS

Packaging methods and the packaging sealing requirements for parts and components that have been precision-cleaned are specified in this section. The requirements in this section are also applicable to VC and VC + UV cleanliness levels.

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10.1 Procedures

Packaging of precision-cleaned parts and components shall be controlled by documented procedures.

10.2 Precision Packaging

Items cleaned to levels stricter than Level 100 (such as Levels 50 and 25) shall be assembled as soon as possible after cleanliness verification.

10.2.1 Environment

All packaging operations shall be accomplished in a cleanroom or in a laminar flow clean workstation.

10.2.2 Equipment

Heat-sealing devices shall be maintained in a clean operational condition at all times. Functional verification tests shall be performed at regular intervals to verify temperature and timing cycles.

10.2.3 Handling of Components

Precision-cleaned components shall be handled with clean, low-lint, white, non-contaminant-generating gloves constructed of an approved material compatible with cleaning fluids or with the hardware application. Items cleaned to visual cleanliness levels shall be handled as described in Section 8.1.4.

10.2.4 Packaging Techniques and Materials

Items cleaned to a precision cleanliness or VC + UV level shall be packaged using the double-bagging technique. Materials used for double bagging shall conform to the requirements of this section and Table V, Appendix B.

LOX parts, components, subsystems, and systems shall be protected by an inner bag of LOX-compatible film, as specified in Table V, Appendix B, unless surfaces which will be in contact with oxygen are effectively sealed (capped or plugged) from particles that may slough or shed from the inner bag.

Note: LOX-compatible bags must be sealed on all sides and must never be center-folded.

10.2.5 Sealing Orifices

The sealing tape used to seal orifices shall be a poly vinyl chloride type.

10.2.6 Inner Bag Purging Gases

When purging is specified, the purging material shall be a clean dry, inert gas such as argon, nitrogen, or equivalent.

10.3 Packaging of Small Items

Each item shall be in a separate, purged, heat-sealed compartment, such that each compartment can be separated from the others by cutting without degrading the integrity of the remaining compartments. The sandwich package, in turn, shall be sealed in a bag of appropriate outer packaging material.

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10.4 Packaging of Large, Heavy, or Odd-Shaped Items

Items which cannot normally be heat sealed in a transparent film bag because of size, weight, or configuration and have precision-cleaned interior surfaces shall be prepackaged using caps, plugs, plastic sheet, and plastic overwrap to cover all exposed surfaces. The packaging materials shall be compatible with system fluids and cleanliness levels.

10.5 ESD Controls

Electrical or electronic hardware that is sensitive to electrostatic discharge (ESD) damage shall be packaged in special antistatic packaging with suitable ESD controls that meet the requirements given in Table VI, Appendix B. Contamination control packaging shall not be placed inside ESD control packaging.

10.6 Certification Decals

The bagged item shall be marked with a decal containing identification, inspection, and certification of cleanliness information.

Note: Decals procured to meet the requirements of this section are not intended for direct application to parts or equipment and the decals need not be compatible with fuels or oxidizers.

11.0 STORAGE AND PROCESSING OF PRECISION CLEANED AND VC ITEMS

All VC or precision cleaned items shall be stored in an enclosed area where temperature and humidity are controlled. Precision cleaned items shall be protected from contamination during any processing that follows cleaning. Assembly, repair, maintenance, and inspection of visible- or precision cleaned hardware shall be conducted in an ISO Class 8 or better cleanroom. If use of a cleanroom is not possible, the area shall be refitted and certified as a controlled work area to minimize exposure of precision-cleaned surfaces to the local environment.

Fluid line connections shall be sealed when not in use to ensure equipment cleanliness integrity. Upon completion of all required processing, the cleaned item or assembly shall be double bagged per Table V, Appendix B. All precision cleaned fluid systems configured for flight shall have integrity seals installed.

11.1 Facility Interfaces with Flight Hardware

Whenever ground support equipment/JSC facilities interface with precision-cleaned flight fluid systems, a supply interface/final filter shall be located as close to the flight hardware interface as possible. Interfacing non-flight hardware shall be cleaned to at least the cleanliness level of the flight hardware. Interfacing fluid hardware (such as hoses, servicing units) shall be handled with the same cleanliness procedures as flight hardware.

Note: Interface filters are required on outlet lines if it is determined that some operations, such as servicing or deservicing fluids, could permit flow in a reverse direction.

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11.2 Assembly, Cleaning, Flushing, and Testing Fluids

Residual cleaning, flushing, and testing fluids shall be removed prior to charging the hardware with the operating fluid.

Note: When fluids are used for assembly, cleaning, flushing, and testing of precision cleaned hardware, the fluid container surface cleanliness requirement is the same as the surface cleanliness level required by the operational system this fluid is to be used within. Removal by flushing with the operating fluid is permitted when appropriate.

11.2.1 Fluid Sampling

All phases of fluid sampling shall be the responsibility of the operating organization. Documented procedures shall be used for sampling and for contamination control during sampling.

11.3 Inspection

The stored precision cleaned items shall be inspected visually before each use for the integrity of the outer bag. A sample of the items in each lot shall be visually inspected through the inner bag for evidence of corrosion or other surface degradation of the packaged item. Any discoloration or visible contamination shall be cause for rejection and re-cleaning of all items in the entire sampled lot. JSC Form 1615 or equivalent shall be used to document the results of inspection and/or re-cleaning.

11.4 Access Controls

Adequate controls shall be established to limit access to storage areas for precision cleaned items to personnel specifically trained in the handling of precision cleaned items.

12.0 MICROBIOLOGICAL CONTAMINATION CONTROL

A primary area of concern for microbiological control is the deionized (DI) water employed in the precision cleaning cycle. Growth of biological organisms is favored in DI water. The presence of biological organisms can lead to degradation of packaged and cleaned hardware, especially on long-term storage in an adverse environment where metabolic activity occurs.

The following requirements shall be met for microbiological control throughout the aqueous precision cleaning cycle.

- The DI water used for cleaning and rinsing for precision cleaning shall be changed at least once every 24 hours.
- The empty tanks shall be visually inspected for build up of algae or other biological organisms. Cleaning of the tanks shall be performed to remove any visible organisms prior to refilling.

Note: Detailed guidelines for microbiological contamination control are provided in documents SP-5076, ISO 14698 Parts 1 and 2, IEST-RP-CC023.1, and MIL-HDBK-408.

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13.0 FOREIGN OBJECT DEBRIS

Foreign object debris (FOD) is a substance, debris, or article alien to a system that would potentially cause damage to the product. Examples of FOD include tools used over or in close proximity to flight hardware or left in the workplace following use; metal or wire clippings, solder balls, and other debris lying in the vicinity of electrical terminals, circuitry, connectors, and components; manufacturing and construction debris; and spilled liquid on walking surfaces. The FOD control program shall be in accordance with the JSC FOD Prevention Program.

14.0 Cleanroom Garments

The minimum requirements for the materials, construction features, laundering processes, and controls for cleanroom garments and accessories, including biologically clean garments, are stated below. Note: Detailed guidelines are provided in ISO 14644 Part 5, IEST-RP-CC003.2, and U.S. Air Force T.O. 00-25-203.

14.1 General

14.1.1 Garment Construction

The garment shall cover the body adequately and shall incorporate adjustable collars and cuffs to give a snug fit. It shall not have pockets. The garment material shall exhibit limited linting characteristics and shall comply with the requirements of this section.

Where antistatic garments are required for ESD control, the selected garments shall have surface resistivity greater than 10^5 ohms per square but not greater than 10^{12} ohms per square. (Table VI, Appendix B).

14.1.1.1 Fabric

Garments shall be of a 100% synthetic textile fiber, such as Dacron or nylon, of a white or pastel color, and have a taffeta or herringbone twill weave.

14.1.1.2 Thread

The thread shall be a continuous filament, stranded, 200 denier, 100% polyester, and of the same color as the garment.

14.1.1.3 Seams

Seams shall be closed, double stitched, and free of loose threads.

14.1.1.4 Style

All smocks and coats shall be at least knee length, and all coveralls shall have full-length legs.

14.1.2 Accessory Construction

14.1.2.1 Head and face coverings

Head and face coverings shall cover hair fully.

14.1.2.2 Shoe Coverings

The tops of the shoe covers shall be made of the same material as the basic garment, be high enough to cover the coverall pants legs, and be secured to the pants legs by either a tie or snaps. The soles shall be made of skid-resistant plastic or other acceptable material.

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14.1.2.3 Booties

Booties shall be made of stretch nylon, or equivalent material, one-size design, with coverage of leg to mid-calf. The use of other types of shoe coverings shall be subject to approval by the Safety and Test Operations Division.

14.1.2.4 Gloves

Gloves shall be a form-fitting design and shall provide complete coverage.

14.2 Laundering Requirements

All laundering shall be conducted in facilities that provide contamination control compatible with the cleanliness requirements for the garments.

Note: Recommended criteria for laundering facilities for garments, as well as criteria for packaging of the laundered garments, are given in U.S. Air Force T.O. 00-25-203.

14.3 Inspection and Sampling

14.3.1 Visual Inspection

Cleanroom garments shall be inspected visually for needed repairs, missing snaps, and broken zippers, as well as for breakdown of the fabric by loose fiber ends protruding from the surface. UV or black light inspection shall be performed for the presence of hydrocarbon stains, such as oil or grease. This visual inspection shall be the responsibility of the user.

14.3.2 Sampling

Two percent of each shipment shall be sampled to ensure that garments comply with particulate cleanliness requirements listed in Section 14.4.1. The responsibility for compliance shall be with the user. Particle counts shall be determined in an environment equal to or better than the environment where the garment was cleaned, if possible, using an approved procedure.

14.4 Acceptance Criteria and Limits

14.4.1 Particulate

The maximum permissible concentration of particles and fibers per square meter of fabric surface shall not exceed 21,520 particles of 5 µm and larger (2000 particles per square foot), with a maximum of 25 fibers. Higher concentrations shall be cause for rejection of the entire lot and re-cleaning of the garments.

14.4.3 Hydrocarbons

The garments shall have no visible hydrocarbons, such as oil stains or grease, as determined by UV light.

14.4.4 Packaging

Each garment shall be packaged individually. The bags that are torn, punctured or otherwise damaged shall be cause for rejection of the garments in that entire lot.

14.4.5 Certification

The supplier shall submit certification showing evidence of compliance with these requirements with each shipment.

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15.0 CONSUMABLES

Consumables for use in cleanrooms and laminar flow clean workstations include wipers, swabs, markers, paper, hand tools, cleaning fluids such as IPA for wiping, small storage containers, and similar items. These items shall be designed specifically for cleanroom use and shall be procured accordingly. If ESD control is essential, the required work items shall be constructed from suitable static dissipative materials, or designed with appropriate control measures.

16.0 ECA PERSONNEL DISCIPLINES AND PROTOCOLS

The requirements of this section are applicable to all operational, quality, technical, maintenance, and management personnel who require entry into an ECA. Since human activity is one of the main sources of contamination, it is mandatory to institute strict personnel discipline with appropriate protocols to minimize the contamination risk. The protocols shall be defined in approved detailed procedures for each user facility to include the following activities.

- Personnel hygiene and health
- Gowning system
- Cleanroom entry and exit
- Movement and actions
- Personnel discipline (smoking, eating and drinking, proper use of protective clothing, and other functions)
- Operations discipline (storage of garments and consumables, wipedown, material ingress and egress, and other functions)
- Monitoring and auditing

Note: Detailed procedures for personnel discipline and appropriate cleanroom protocols are provided in ISO 14644, Part 5, IEST-RP-CC027.1, and U.S. Air Force T.O. 00-25-203.

17.0 PERSONNEL TRAINING

This section defines the minimum training requirements for all personnel associated with contamination control activities.

17.1 Training for Environmentally Controlled Area Disciplines

Personnel training for individual ECA operations is required and shall be accomplished by all personnel by the successful completion of a formal training program in each unit operation, as applicable, to their particular job responsibilities and how those responsibilities interact with the ECA environment.

Visitors requiring entry to the ECA shall be knowledgeable in the basic ECA protocols, or they shall be formally instructed in these protocols before entering the particular ECA facility. They shall be escorted at all times by qualified personnel.

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Note: The appropriate ECA supervisor controls entry of visitors or temporary personnel to prevent overpopulation and compromise of ECA integrity.

17.2 Qualification Status

Personnel qualification status shall be obtained as specified below.

17.2.1 Previous Qualifications

Personnel previously trained for individual ECA operations at JSC shall furnish the responsible training officer with copies of training results, certificates, or any other data requested for proof of qualification.

17.2.2 New Employees

New employees granted temporary permits for ECA entry shall only be granted such permits after they have been verbally indoctrinated in ECA entry procedures, garment donning procedures, and ECA rules and regulations. These personnel shall complete formal training in site-specific contamination control requirements before the expiration of their temporary permit.

Note: New employees may be issued temporary permits for entry into the ECA facility for periods not to exceed 90 days. Formal training should be complemented with on-the-job training.

17.2.3 Training Records

The ECA operating organization shall maintain records for and listing of all employees and the specific operations for which they are qualified.

17.3 Certificate

Upon successful completion of the appropriate qualification requirements, a certificate of training will be issued. This certificate shall bear the signature and title of the authorized training officer. The training officer shall be the person providing the certification training.

17.4 Retraining and Qualification

Training certification shall be valid for a period of two years from the date of the first or last successful training course.

Note: The authorized training officer or the responsible division, branch, or section chief may require a person to be retrained any time there is reason to question the proficiency of the individual.

18.0 Reference Documents

The documents listed in this section provide the guidelines necessary to develop detailed procedures for effective contamination control.

18.1 NASA Documents

- a. NSTS 08131C, "Space Shuttle Contamination Control Plan"
- b. SSP-30426, "Space Station External Contamination Control Requirements"
- c. KSC-C-123, "Specification for Surface Cleanliness of Fluid Systems"
- d. MSFC-PROC-166D, "Procedures for Cleaning, Testing, and Handling Hydraulic System Detailed Parts, Components, Assemblies, and Hydraulic Fluids for Space Vehicles"

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- e. MSFC-SPEC-164A, "Specification for Cleanliness of Components for Use in Oxygen, Fuel, and Pneumatic Systems"
- f. MSFC-STD-246, "Standard Design and Operation Criteria of Controlled Environmental Areas"
- g. NSTS 07700, Volume XIV, "Space Shuttle System Payload Accommodations," Section 3.6.12, "Contamination Control"
- h. NSTS 08242, "Limitations for Nonflight Materials and Equipment Used in and Around the Shuttle Orbiter Vehicles"
- i. SE-S-0073, "NSTS Specification, Fluid Procurement and Use"
- j. SN-C-0005, "Contamination Control Requirements for the Space Shuttle Program"
- k. SP-5076, "Contamination Control Handbook"
- l. NX-PRE-003, "Cleanliness and Cleanroom Certification Contamination Control"
- m. NT-QAS-018, "Quality Assurance Specialist or Designated Verification Personnel Functions in Cleaning Facilities"
- n. JSC Form JF1615, "Clean Room Work Request and Laboratory Report"

18.2 Military Documents

- a. MIL-A-18455C, "Argon, Technical"
- b. MIL-P-27401, "Nitrogen, Grade A, B, or C"
- c. MIL-HDBK-406, "Cleaning Materials for Precision-Cleaning and Use in Clean Rooms and Clean Work Stations"
- d. MIL-HDBK-407, "Precision Cleaning Methods and Procedures"
- e. MIL-HDBK-408, "Microbial Deterioration in Electronics. Its Origin and Control"
- f. TO 00-25-203, "Contamination Control of Aerospace Facilities, US Air Force"
- g. MIL-STD-2073/1D, "Standard Practice for Military Packaging"

18.3 ASTM Standards and Practices

- a. ASTM D770-99, "Standard Specification for Isopropyl Alcohol"
- b. ASTM D2109-01, "Standard Test Methods for Nonvolatile Matter in Halogenated Organic Solvents and Their Admixtures"
- c. ASTM F51-00, "Sizing and Counting Particulate Contamination In and On Clean Room Garments"
- d. ASTM F307-02, "Standard Practice for Sampling Pressurized Gas for Gas Analysis"
- e. ASTM F318-78, "Standard Practice for Sampling Airborne Particulate Contamination in Clean Rooms for Handling Aerospace Fluids"
- f. ASTM E1235-01, "Standard Test Method for Gravimetric Determination of Nonvolatile Residue (NVR) in Environmentally Controlled Areas of Spacecraft"
- g. ASTM E595-93, "Standard Test Method for Total Mass Loss and Collected Volatile Condensable Materials From Outgassing in a Vacuum Environment"
- h. ASTM F24-00, "Standard Method for Measuring and Counting Particulate Contamination on Surfaces"
- i. ASTM Manual 36, "Safe Use of Oxygen and Oxygen Systems. Guidelines for Oxygen System Design, Materials Selection, Operations, Storage, and Transportation"

18.4 Institute of Environmental Sciences Publications

- a. IEST-RP-CC002.2, "Unidirectional Flow Clean Air Devices"

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- b. IEST-RP-CC003.2, “Garments Required in Cleanrooms and Controlled Environments”
- c. IEST-RP-CC004.2, “Evaluating Wiping Materials Used in Cleanrooms and Other Controlled Environments”
- d. IEST-RP-CC006.2, “Testing Cleanrooms”
- e. IEST-RP-CC023.1, “Microorganisms in Cleanrooms”
- f. IEST-RP-CC026.1, “Cleanroom Operations”
- g. IEST-RP-CC027.1, “Personnel Practices and Procedures in Cleanroom and Controlled Environments”
- h. IEST-STD-CC-1246B, “Product Cleanliness Levels and Contamination Control Program”

18.5 International Organization for Standardization (ISO) Documents

- a. ISO 14644-1, “Cleanrooms and associated controlled environments. Part 1: Classification of air cleanliness”
- b. ISO 14644-2, “Cleanrooms and associated controlled environments. Part 2: Specifications for testing and monitoring to prove continued compliance with ISO 14644-1”
- c. ISO 14644-3, “Cleanrooms and associated controlled environments. Part 3: Metrology and test methods”
- d. ISO 14644-2, “Cleanrooms and associated controlled environments. Part 5: Operations”
- e. ISO 14698-1, “Cleanrooms and associated controlled environments – Biocontamination control. Part 1: General principles and methods”
- f. ISO 14698-2, “Cleanrooms and associated controlled environments – Biocontamination control Part 2: Evaluation and Interpretation of biocontamination data”

18.6 Other References

- a. A - A -1689, “Tape, Pressure-Sensitive Adhesive (Plastic Film)”
- b. SAE-ARP-598, “SAE Aerospace Recommended Practice for the Determination of Particulate Contamination in Liquids by the Particle Count Method”
- c. NFPA B93.19, “Method for Extracting Fluid Samples from the Lines of an Operating Hydraulic Fluid Power System for Particulate Contamination Analysis”
- d. SAE ARP-743, “Procedures for the Determination of Particulate Contamination of Air in Dust Controlled Spaces by the Particle Count Method”
- e. ANSI/ESD S20.20-1999, “Development of an Electrostatic Discharge Control Program for Protection of Electrical and Electronic Parts, Assemblies and Equipment (Excluding Electrically Initiated Explosive Devices)”

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APPENDIX A

ACRONYMS

ANSI	American National Standards Institute
ASTM	American Society for Testing and Materials
CWA	controlled work area
ECA	environmentally controlled area
ESD	electrostatic discharge
FOD	foreign object debris
GC	generally clean
GFE	government furnished equipment
GOX	gaseous oxygen
HEPA	high efficiency particulate air
IEST	Institute of Environmental Sciences and Technology
ISO	International Standards Organization
JSC	Lyndon B. Johnson Space Center
LOX	liquid oxygen
m	meter
mil	one thousandth of an inch
MIL	military
MPa	Megapascal, unit of pressure (1 MPa = 10 bar or 7500 torr)
MSC	Manned Spacecraft Center (Formerly as the Johnson Space Center)
MSFC	George C. Marshall Space Flight Center
NASA	National Aeronautics and Space Administration
NFPA	National Fire Protection Association
NVR	nonvolatile residue
psi	pounds per square inch
psig	pounds per square inch gauge
RH	relative humidity
SAE	Society of Automotive Engineers
S&MA	Safety and Mission Assurance
TOC	total organic carbon
TPS	task performance sheet
UV	ultraviolet
VC	visibly clean
VC + UV	visibly clean plus ultraviolet
µm	micrometer

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Appendix B

Tables

Table I	JSC Baselined Cleanroom Classes by Particle Size Distribution
Table II	ECA Requirements Matrix
Table III	ECA Garment Requirements
Table IV	Surface Cleanliness Levels
Table V	Packaging for Cleanliness Protection
Table VI	ESD Control Program Verification and Measurements

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TABLE I

JSC BASELINED CLEANROOM CLASSES BY PARTICLE SIZE DISTRIBUTION (NOTE 1)

CLEANROOM CLASS (NOTE 2)		MAXIMUM PARTICLE COUNT BY PARTICLE SIZE			
ISO	FED	$\geq 0.5 \mu\text{m}$		SIZE $\geq 5.0 \mu\text{m}$	
		PER M ³	PER FT ³	PER M ³	PER FT ³
5	100	3,520	100	29	< 10 (NOTE 3)
6	1,000	35,200	1,000	293	< 10 (NOTE 3)
7	10,000	352,000	10,000	2,930	65
8	100,000	3,520,000	100,000	29,300	700

NOTES

NOTE 1 Particle size distribution curves may be found in ISO 14644 Part 1.

NOTE 2 Alternative classifications such as ISO 5.4, 6.8 or 7.3 may be used for particle count levels where unique situations dictate their use. For the alternative classifications, the Safety and Test Operations Division will define the maximum particle counts. The Safety and Test Operations Division must also concur in the selection and use of alternative classifications that are not baselined in this table.

NOTE 3 Counts below 10 particles per 0.028 m³ (1.0 ft³) are unreliable except when a large number of samples are taken.

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TABLE II				
ECA REQUIREMENTS MATRIX				
AREA REQUIREMENTS (NOTE 1)	CLEANROOMS		LAMINAR FLOW CLEAN WORK STATIONS	CWAs
	LAMINAR FLOW	NON- LAMINAR FLOW		
ANNUAL CERTIFICATION	X	X	X	—
CONTROLLED BY APPROVED DOCUMENTED PROCEDURES	X	X	X	X
HEPA FILTER SYSTEM	X	X	X	—
POSITIVE PRESSURE	X	X	—	—
AIRBORNE PARTICLE MONITORING	X	X	X	—
TEMPERATURE CONTROL	X	X	—	—
RH CONTROL	X	X	—	—
LAMINAR FLOW CRITICAL	X	—	X	—
ROOM AIR CHANGE CRITICAL	—	X	—	—
SPECIAL TOOL CONTROLS	X	X	X	X
SPECIAL GARMENTS	X	X	X	X
CONTAMINANT-GENERATING OPERATIONS MAY BE AUTHORIZED	—	—	—	X
STRICT PERSONNEL DISCIPLINE	X	X	X	X
FORMAL PERSONNEL TRAINING	X	X	X	X
NOTES				
NOTE 1 This matrix provides a comparison of significant requirements for cleanrooms, laminar flow clean workstations, and CWAs. It should <i>not</i> be inferred that this matrix represents <i>all</i> requirements necessary for the design, operation, and maintenance of ECAs.				

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TABLE III ECA GARMENT REQUIREMENTS				
GARMENT	ECA			
	ISO CLASS 5 (NOTE 1)	ISO CLASS 7	ISO CLASS 8	CWA
COVERALLS	REQUIRED	REQUIRED	OPTIONAL	OPTIONAL
HOODS	REQUIRED	REQUIRED	(NOTE 2)	(NOTE 2)
SMOCKS	-----	(NOTE 3)	REQUIRED	REQUIRED
CAPS	-----	-----	REQUIRED (NOTE 2)	REQUIRED
BOOTIES	REQUIRED	OPTIONAL	OPTIONAL	OPTIONAL
SLIP-ON SHOE COVERS	-----	REQUIRED (NOTE 4)	REQUIRED (NOTE 4)	OPTIONAL
HAND COVERINGS	(NOTE 5)	(NOTE 5)	(NOTE 5)	(NOTE 5)
NOTES				
NOTE 1	Laminar flow clean work stations: Garments are required only for those parts of the body that are extended into the clean work area such as hands, arms, upper torso, facial and head hair.			
NOTE 2	Hoods shall be worn when caps do not fully cover facial and head hair.			
NOTE 3	Smocks may be used in lieu of coveralls in ISO Class 7 (FED Class 10,000) vertical laminar flow cleanrooms provided applicable airborne particulate requirements are met.			
NOTE 4	Shoe coverings may be deleted from use in these classes of vertical laminar flow cleanrooms provided applicable airborne particulate requirements are met.			
NOTE 5	The use of hand coverings such as gloves depends upon the type of operation being performed. Hand coverings are mandatory for handling exposed critical surfaces of precision or VC + UV cleaned items. When hand coverings are used in the handling of LOX/GOX components with exposed critical surfaces, they shall be constructed of an approved, compatible material.			

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TABLE IV
SURFACE CLEANLINESS LEVELS

VISUAL CLEANLINESS LEVELS

Generally Clean (GC) (NOTE 1). Free of manufacturing residue, dirt, oil, grease, processing debris or other extraneous contamination. This level can be achieved by washing, wiping, blowing, vacuuming, brushing, or rinsing. The GC level shall not be designated for hardware that is sensitive to contamination.

Visibly Clean (VC) (NOTE 2). Free of all particulate and non-particulate matter visible to the normal unaided eye (corrected vision acceptable). Particulate matter is identified as contaminants of miniature size with observable length, width, and thickness. Non-particulate matter is identified as contaminants without definite dimension such as surface films. This level requires precision-cleaning methods, but no particle count.

Visibly Clean Plus Ultraviolet (VC + UV) (NOTE 2). VC (as defined above) and inspected with the aid of an ultraviolet light (black light) of 3,200 to 3,800 angstroms wavelength. This level requires precision-cleaning methods, but no particle count.

NOTE - Any evidence of fluorescence shall be cause for re-cleaning. If re-cleaning does not reduce the fluorescence, an investigation shall be made to determine whether the fluorescing material is contamination or the basic material.

<u>PRECISION PARTICULATE LEVELS</u>			<u>NONVOLATILE RESIDUE (NVR) LEVELS</u>	
PARTICLE SIZE RANGE			MAXIMUM QUANTITY NVR PER 0.1 M² (1.08 FT²)	
<u>LEVEL</u>	<u>MICROMETERS</u>	<u>(NOTES 3, 4, AND 6)</u>	<u>LEVEL</u>	<u>(NOTES 3 AND 6)</u>
1,000	< 500	UNLIMITED (NOTE 5)	A	1 milligram
	500 thru 750	34	B	2 milligrams
	> 750 thru 1,000	5	C	3 milligrams
	> 1,000	0	D	4 milligrams
750	< 250	UNLIMITED (NOTE 5)		
	250 thru 500	205		
	> 500 thru 750	9		
	> 750	0		
500	< 100	UNLIMITED (NOTE 5)		
	100 thru 50	1,075		
	> 250 thru 500	27		
	> 500	0		
300	< 100	UNLIMITED (NOTE 5)		
	100 thru 250	93		
	> 250 thru 300	3		
	> 300	0		
250	< 100	UNLIMITED (NOTE 5)		
	100 thru 200	39		
	> 200 thru 250	3		
	> 250	0		
(CONCLUDED NEXT PAGE)				

TABLE IV (CONCLUDED)
SURFACE CLEANLINESS LEVELS

PRECISION PARTICULATE LEVELS (CONCLUDED)

PARTICLE SIZE RANGE			PARTICLE SIZE RANGE		
LEVEL	MICROMETERS	(NOTES 3, 4, AND 6)	LEVEL	MICROMETERS	(NOTES 3, 4, AND 6)
250	< 100	UNLIMITED (NOTE 5)	100 (NOTE 5)	< 25	UNLIMITED
	100 thru 200	39		25 thru 50	68
	> 200 thru 250	3		> 50 thru 100	11
	> 250	0		> 100	0
200	< 50	UNLIMITED (NOTE 5)	50 (NOTE 5)	< 10	UNLIMITED
	50 thru 100	154		15 thru 25	17
	> 100 thru 200	16		> 25 thru 50	8
	> 200	0		> 50	0
150	< 50	UNLIMITED (NOTE 5)	25 (NOTE 5)	< 5	UNLIMITED
	50 thru 100	47		5 thru 15	19
	> 100 thru 150	5		> 15 thru 25	4
	> 150	0		> 25	0

EXAMPLE: Level 300 would be particulate Level 300. Level 300C would be particulate Level 300 plus NVR Level C.

NOTES

- NOTE 1 GC items *do not* require cleaning before inspection; cleaning is required *only* if the item does not pass GC inspection.
- NOTE 2 Surface cleaning with an approved, compatible solvent is mandatory for VC and VC + UV items, unless other methods are required for the hardware in question.
- NOTE 3 Allowable particulate and NVR levels are based on 0.1 m² (1.08 ft²) of surface area. Flush fluid quantity for sampling shall be 100 milliliters per 0.1 m² (1.08 ft²) of surface area. Small parts should be grouped together to obtain 0.1 m² (1.08 ft²) of surface area.
- NOTE 4 Maximum quantity per 1.0 m³ (35.31 ft³) of effluent gas when systems are being evaluated by purging. If feasible, the sampling must be performed at the maximum system operation flow rate.
- NOTE 5 "Unlimited" means particulates of this size and smaller are not counted. However, if the accumulation of particulates of these size is sufficient to interfere with the analysis, the sample shall be rejected.
- NOTE 6 Other precision particulate levels or residue analyses (such as Levels 80, 400, 800, or total hydrocarbon content analysis) may be specified when design requirements dictate their use. The Safety and Test Operations Division must concur in the selection and use of classifications that are not baselined in this table.

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TABLE V
PACKAGING FOR CLEANLINESS PROTECTION

CLEANLINESS REQUIREMENT	PACKAGING TECHNIQUE AND MATERIAL REQUIREMENTS
All precision-cleaned items except (1) items for LOX service, or (2) for GOX service at > 5.516 MPa (800 psi)	Double-bagging technique required. <i>Inner</i> bag of Nylon 6, approximately 51 μm (2 mils) thick. <i>Outer</i> bag of antistatic polyethylene film, approximately 152 μm (6 mils) thick. Aclar 22A, FEP Neoflon, and FEP Teflon films may be used instead of nylon 6 for the <i>inner</i> bag.
Precision-cleaned items for (1) LOX service, or (2) GOX service at > 5.516 MPa (800 psi)	Double-bagging technique required. <i>Inner</i> bag of Aclar 22A, approximately 38 μm (1.5 mils) thick. <i>Outer</i> bag of antistatic polyethylene film, approximately 152 μm (6 mils) thick. FEP Neoflon and FEP Teflon may be used instead of Aclar 22A for the <i>inner</i> bag film.
Items cleaned to VC + UV level	Double-bagging technique required. <i>Inner</i> bag of nylon 6, approximately 51 μm (2 mils) thick. <i>Outer</i> bag of antistatic polyethylene film, 152 μm (6 mils) thick (NOTE 4).
Items cleaned to VC level	Shall be <i>single-bagged</i> . Bag shall be antistatic polyethylene film, approximately 152 μm (6 mils) thick (NOTE 1).
GC-cleaned items	No precision packaging is required. Protective packaging as required for storage, shipping, and preservation (NOTES 2, 3).

NOTES

- NOTE 1 The cleanliness certification decal is applied to the outside of the single bag.
- NOTE 2 At JSC, GC hardware in transit between facilities shall be environmentally protected. Acceptable means of protection include plastic boxes with snug-fitting covers or reusable, non-heat sealed plastic bags. Hardware compatible foam or other acceptable means of cushioning may be used if necessary. Deteriorated or contaminated boxes or bags shall not be used.
- NOTE 3 The GC level does not require a cleanliness certification sticker, since protective contamination control packaging is not required.
- NOTE 4 Antistatic polyethylene film (pink polyethylene, purple polyethylene or similar film) shall not contain tertiary amine compounds, which may cause metal corrosion. Antistatic agents may affect sensitive optical surfaces.

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TABLE V ESD CONTROL REQUIREMENTS AND SPECIFICATIONS	
ITEM	REQUIREMENT AND SPECIFICATION
Work surface resistivity (NOTE 1)	$\geq 10^5$ to $< 10^9$ ohm/square
Work surface grounding	Surface shall be static dissipative and electrically connected to common point ground
Work surface solvent resistance	Resistance to JSC approved solvents and cleaners required
Work surface static charge dissipation	Surface shall be static dissipative
Conductive floor resistivity	$< 10^9$ ohm/square
Wrist strap release force	≥ 8.9 to < 22.2 Newtons (2 – 5 pounds)
Wrist strap system resistance	$< 35 \times 10^6$ ohm
Foot grounding device integrity	Acceptable alternative to wrist strap. Integrity shall be verified similarly to wrist strap
Equipment and facility grounding (NOTE 2)	< 1.0 ohm AC impedance
Stool and chair grounding (NOTE 2)	Shall be constructed of conductive material with static dissipative cover material ($< 10^9$ ohm/square surface resistivity)
Relative humidity (RH)	Required range $> 30\%$ to $< 70\%$ RH Preferred range $> 40\%$ to $< 60\%$ RH
Mobile equipment grounding (NOTE 2)	< 1.0 ohm AC impedance
Ionization (NOTE 2)	Room and/or local air ionization required. Nuclear or corona discharge ionizers acceptable. Room ionization: $< \pm 150$ Volts. Local ionization: $< \pm 50$ Volts
Soldering iron tip to ground	< 1.0 ohm AC impedance
ESD monitoring	Required using non-contact surface measurement
Garment	$> 10^5$ to $< 10^{11}$ ohm/square surface resistivity
Packaging	Static dissipative $> 10^5$ to $< 10^{11}$ ohm/square surface resistivity
NOTES	
NOTE 1	Surface resistivity is numerically equal to the surface resistance between two electrodes forming opposite sides of a square of the material. The size of the square is irrelevant over a wide range of sizes. Units are ohms per square (ohms/square)
NOTE 2	Proof of verification is required prior to use by some form of identification such as label, tag, or stick
GENERAL	Records shall be maintained for all items for verification prior to use. Items not in compliance shall be rendered unusable until corrective actions are complete

Verify that this is the correct version before use.